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GROUND TRACKING RELIABILITY - A SUMMARY FROM GEMINI FLIGHTS GTA 9, 10, 11, AND 12

FORD KALIL

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GODDARD SPACE FLIGHT CENTER
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ABSTRACT

This report contains data, in both tabular and graphical form, regarding the reliability of the ground network as configured for support of Gemini, in particular the down-times of the various network functions such as: acquisition, radar range, radar angles, timing, telemetry, commands, spacecraft communication (voice), on-site computer, NASCOM teletype and high speed data. The down times reported are only those which occurred during Gemini flights GTA-9, 10, 11, and 12; i.e., launch to splash. The down time is that time from when the function was reported "red" until it was reported "green." The percent of time down for these various functions varied from 0.04% for the NASCOM teletype to 4.8% for the C-Band radar ranging function. (See Table VIII).

This work was done in response to the Apollo Navigation Working Group (ANWG) action item (minutes of the February 23-24 ANWG Meeting) regarding data on the ground network failure modes, for use in evaluating the ground network capabilities, including contingencies, for support of Apollo.

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I. SUMMARY OF RESULTS

The down time histograms indicate a Poisson type distribution for the various functions of interest. The functions or systems which are of interest from a navigation viewpoint and the percentage of time these functions were down, i.e., inoperable, during the Gemini flights GTA-9/9A, 10, 11, and 12 are as follows:

1. Acquisition, 3.7%
2. Radar range (C-Band), 4.8%
3. Radar angles (C-Band), 0.23%
4. Timing, 0.21%
5. Telemetry (Down-Link), 2.5%
6. Command (Up-Link), 0.65%
7. Spacecraft Communications (Voice), 2.4%
8. On-Site Computers, 0.20%
9. NASCOM (Ground communications), 0.041% for TTY, and 3.1% for HSD.

The down time histograms and other data are presented herein for only the time during spacecraft flight and thus represents the network at its peak performance, because prior to flight, the network is being "peaked" up via brief and detailed systems tests, and weak or bad "components" are replaced in order to bring the stations to peak operating condition for support of the flight.

II. INTRODUCTION

In the Apollo Program Directive No. 17 of March 31, 1966, "Apollo Navigation Working Group (ANWG)," (ref. 1), it states that the ANWG... "is assigned the responsibility of providing information and recommendations concerning the individual and/or combined utilization of Apollo tracking and navigation systems

to best perform the Apollo mission." In order to comply with this directive, extensive analysis of the navigational capabilities of the Manned Space Flight Network (MSFN) have been performed by the ANWG (see refs. 2 and 3). In that work, it was assumed all tracking functions of the MSFN stations are operational 100% of the time. For future analyses, a more realistic approach may need to be taken which takes into account various tracking function failures.

Although there is presently very little data based on flight experience about the reliability of the Unified S-Band Systems (USBS), there is significant data from the Gemini missions and that data is presented herein.

Steps have been taken to obtain in the future the desired reliability data regarding the USBS via the equipment logs which have been modified to include the requirements of the ANWG. The equipment logs are reported, signed by each system or subsystem supervisor at the sites, and submitted to GSFC on a weekly basis during non-mission status and daily during mission status, (see ref. 4).

III. PURPOSE

The purpose of this report is to present the ground systems reliability data, primarily the down times, and number of failures as obtained from references 5, 6, 7, and 8 for Project Gemini, during the flights GTA-9, 10, 11, and 12.

IV. GEMINI GROUND SYSTEMS RELIABILITY DATA

A summary of the number of failures and the total down time for those failures which occurred during the flights of Gemini missions GTA-9, 10, 11, and 12 is given in Table I for each station and each subsystem or function. The ground station capabilities and the flight times for these missions are given in Tables II and III, respectively.

A listing of the down times for each failure according to subsystem is given in Tables IV, V, VI, and VII for Gemini missions GTA-9, 10, 11, and 12, respectively. The down times from all these missions are also plotted in histogram form in Figures 1 through 10, for each subsystem in order to show the down time distribution. The normalized down time shown is the down time per mission support hour; where the mission support hour is the product of the total

flight time for the four missions being considered times the number of subsystems or systems in the network which had to be "up" for support of these missions.

In the case of the C-band radars, the failures are presented here for the range measurement and angle measurement functions independently. References 5 and 8 did not always distinguish between range and angle failures. Unless a failure was identified as an angular failure, it was assumed to be a range failure. Furthermore, if the radar was not identified, it was assumed to be a C-Band radar.

The down times reported are the times from when a system or function was reported "red" until it was reported "green" by the site. This means that the down time includes the time to diagnose the failure, obtain parts or spares as necessary, correct or repair, and "check-out" the function. In order to be conservative, the down times shown herein are the largest of the down times reported via the: (a) station status reports, (b) equipment log, and (c) the network controller's report (see ref. 8 for example).

In the case of the range measurement function, a time between failures histogram is also shown in Figure 1a, in addition to the down time histogram shown in Figure 1b. The time between failures for the other systems or functions is not presented at this time, but will be reported in subsequent revisions. In the case of the first failure, the time between failure is in reality the time to failure from the start of terminal count.

V. ACKNOWLEDGEMENTS

In this undertaking it was necessary to contact and work in close cooperation with many people. I would like to take this opportunity to thank these people for their helpful suggestions, comments, and cooperation, in particular, H. W. Wood, J. Donegan, R. Liebermann, F. Kallmeyer, W. E. Laumann, A. Hampton, and J. Cook.

VI. REFERENCES

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3. MSC-GSFC, ANWG Technical Report No. AN-2.1, "Apollo Navigation - Ground and Onboard Capabilities," September 1, 1966.
4. "Network Operations Directive for NASA Manned Space Flight Operations," contact Manned Flight Operations Branch, Goddard Space Flight Center, November 1, 1966.
5. "Network Performance Analysis for the Gemini GTA-9/9A Mission," approved by H. W. Wood, Manned Flight Operations Branch, GSFC, Report No. X-552-66-438, December 23, 1966.
6. "Network Performance Analysis for the Gemini GTA-10 Mission," approved by H. W. Wood, Manned Flight Operations Branch, GSFC, Report No. X-552-66-589, December 28, 1966.
7. "Network Performance Analysis for the Gemini GTA-11 Mission," approved by H. W. Wood, Manned Flight Operations Branch, GSFC, Report No. X-552-66-590, December 29, 1966.
8. "Network Performance Analysis for the Gemini GTA-12 Mission," approved by H. W. Wood, Manned Flight Operations Branch, GSFC, Report No. X-552-67-36, February 1967.

Table I
Summary of Number of Ground System Failures and Total Down Times (hours)
during Gemini Flights GTA-9/9A, 10, 11, and 12
(See Tables IV, V, VI, and VII for down times during each mission.)

System Station	Number of Failures/Total Down Time, Hours (1)										TOTALS	
	Acq. Aid	C-Band Radars		Timing Standard	Telemetry Down-Link	Command Up-Link	S/C Com. Up-Link Voice	On-Site 1218 Computer	NASCOM TTY	NASCOM HSD	Failures	Down Time (hrs)
		Range	Angles									
MCC-K	1/24			1/3	2/22					NA	4	47.0
MLA	NA	1/0.5			NA	NA	NA	NA	NA	NA	1	0.5
CNV								1/1.0		NA	1	1.0
PAT	NA				NA	NA	1/0.75	NA	NA	NA	1	0.75
GBI		1/0.5	1/0.25			1/2.75	1/64.0	NA		NA	4	67.5
GTK						1/1.0		NA		NA	1	1.0
BDA	3/6.0	6/11.5	3/12.75		1/2.0		1/3.0			1/22.5	15	54.0
ANT	NA	1/8.0	1/0.5			NA	NA	NA	NA	NA	2	8.5
CYI		1/8.5								NA	1	8.5
ASC	NA				1/90.0	NA	1/8.0	NA	NA	NA	2	98.0
KNO		NA	NA		1/12.0	NA	1/3.0	NA		NA	2	15.0
PRE	NA				NA	NA	NA	NA	NA	NA		
TAN	1/0.5	NA	NA			NA		NA		NA	1	0.5
CRO		6/124.75		2/6.5	2/4.0	7/18.0	2/2.75	1/1.5	1/0.5	NA	21	157.25
WOM		1/0.25		1/0.75	NA	NA	NA	NA	1/0.25	NA	3	1.25
CTN		NA	NA		2/3.0	NA	3/11.0	NA		NA	5	14.0
HAW	1/5.0	1/1.5			1/3.0	3/6.0		1/3.0	2/2.0	NA	9	20.5
CAL	2/12.0	8/28.75			1/19.0	NA	1/4.0	NA		NA	14	67.5
GYM	1/0.25	3/7.0	1/0.5	2/4.0	1/1.5	NA	3/29.5			NA	11	43.0
WHS					NA	NA	NA	NA		NA		
TEX						3/11.0	3/4.75	1/1.75			7	17.5
EGL	1/96.0	2/97.5				NA	NA	NA		NA	3	194.0
SHIPS	1/96.0	2/5.5		1/2.5	1/3.0	2/5.5	2/6.0		1/0.25	NA	10	119.0
TOTAL FAILURES	11	33	6	7	13	17	19	4	5	1	116	
Total Down Time, hrs	239.75	294.25	14.0	16.75	159.5	44.25	136.75	7.25	3.0	22.5		938
Avg. No. of "Systems" (2)	18	17	17	22	18	19	16	10	20	2		
Mission Support Time in hours (3)	6500	6140	6140	7940	6500	6860	5780	3610	7220	722		
% of Time Down	3.7	4.8	0.23	0.21	2.5	0.65	2.4	0.20	0.041	3.1		
Failures/1000 hrs (4)	1.7	5.4	0.98	0.88	2.0	2.5	3.3	1.1	0.69	1.4		

(1) Down Time is the time from when a function or system was reported "red" until it was reported "green" at a given station.

(2) Avg. No. of "Systems" = Average number of stations with the given capability and called on for support during the GTA-9/9A, 10, 11, and 12 missions, because the network configuration varied from flight to flight, particularly in the ship's support.

(3) Mission Support Time = Total flight time of 360.5 hrs for GTA-9/9A, 10, 11, and 12 missions multiplied by the average number of "Systems."

(4) No. of Failures per 1000 mission support hours, rounded off to two significant figures.

Table II
Summary of Capabilities at Network Stations
(Gemini Support)

System Station	Acquisition Aid	Radar (C-Band)	PCM TLM	TLM Record	PAM TLM (FM/FM)	Display Consoles	Digital Command	RF Command	Timing Standard (ETR or NASA)	Spacecraft Com-munications	SCAMA	Teletype	High Speed Data	Wide Band Data	Intercom	Computer 7094	Computer 1218
Cape Kennedy (CNV) and Mission Control Center (MCC-K)	X	X	X	X	X	X	X	X	N	X	X	X		X	X		2
Grand Bahama Island (GBI)	X	X	X	X	X			X	E	X	*	X			X		
Grand Turk Island (GTK)	X	X	X	X				X	E	X	*	X			X		
Bermuda (BDA)	X	X	X	X	X			X	N	X	X	X	X		X		X
Antigua (ANT) when coordinated		X	X	X	X				E		*				X		
Canary Island (CYI)	X	X	X	X	X	X	X	X	N	X	X	X			X		X
Ascension Island (ASC) when coordinated	X			X	X				E		*				X		
Kano (KNO)		X		X	X				N	X	X	X			X		
Pretoria (PRE)		X			X				E		X				X		
Tananarive (TAN)	X			X	X				N	X	X	X			X		
Carnarvon (CRO)	X	X	X	X	X	X	X	X	N	X	X	X			X		X
Woomera (WOM) when coordinated	X	X							N		X	X			X		
Canton Island (CTN)	X			X	X				N	X	X	X			X		
Hawaii (HAW)	X	X	X	X	X	X	X	X	N	X	X	X			X		X
California (CAL)	X	X		X	X				N	X	X	X			X		
Guaymas (GYM)	X	X ¹	X	X	X	X			N	X	X	X			X		X
White Sands (WHS)	X	X	X	X	X	X			N	X	X	X			X		
Texas (TEX)	X	X ¹	X	X	X	X	X	X	N	X	X	X	X		X		X
Eglin (EGL)	X	X		X	X				N		X	X			X		
Wallops (WLP)	X	X ²	X	X	X	X	X	X	N	X	X	X			X		
Coastal Sentry Quebec (CSQ)	X		X	X	X	X	X	X	N	X	X	X			X		X
Wheeling (WHE)	X	X							N	X	X	X			X		X
Rose Knot Victor (RKV)	X		X	X	X	X	X	X	N	X	X	X			X		X
Goddard Space Flight Center (GSFC)											X	X			X	X	
Merrit Island (MLA)		X							E								
Patrick A.F. Base (PAT)		X							E	X							
TOTAL W/SHIPS³	20	17	13		18		8	11	23	18		21	2	1			10

* Through Cape Kennedy Operator

¹ S-Band Radar

² Training Only

³ The totals used in subsequent tables or figures may differ because the network configuration varied from mission to mission, in particular, in the ship support.

Table III

Flight Times for GTA-9, 10, 11, and 12

Mission	Launch Date-GMT	Vehicle	Splash Date-GMT	Vehicle	Flight Time, Agena Launch to Gemini Splash, Hours
GTA-9	6-1-66 15:00	Agena			119.0
	6-3-66 13:40	Gemini	6-6-66 14:01	Gemini	
GTA-10	7-18-66 20:40	Agena			72.5
	7-18-66 22:20	Gemini	7-21-66 21:07	Gemini	
GTA-11	9-12-66 13:05	Agena			73.0
	9-12-66 14:42	Gemini	9-15-66 14:00	Gemini	
GTA-12	11-9-66	Agena & Gemini	Postponed		96.0
	11-11-66 19:08	Agena			
	11-11-66 20:47	Gemini	11-15-66 19:21	Gemini	

Table IV
Gemini Network Station Down Times during GTA-9/9A Mission
(119 hours flight time from Agena launch to Gemini splash)

System Station	Acq. Aid	C-Band Radars		Timing Standard	Telemetry Down-Link	Command Up-Link	S/C Com. Up-Link Voice	On-Site 1218 Computer	NASCOM TTY	NASCOM HSD	TOTALS	
		Range	Angles								Failures	Down Time (hrs)
MCC-K					17					NA	1	17
MLA	NA				NA	NA	NA	NA	NA	NA		
CNV										NA		
PAT	NA				NA	NA	0.75	NA	NA	NA	1	0.75
GBI							64	NA		NA	1	64
GTK								NA		NA		
BDA										22.5	1	22.5
ANT	NA					NA	NA	NA	NA	NA		
CYI		8.5								NA	1	8.5
ASC	NA					NA		NA	NA	NA		
KNO		NA	NA			NA		NA	NA	NA		
PRE	NA				NA	NA	NA	NA	NA	NA		
TAN		NA	NA			NA		NA		NA		
CRO		0.25, 0.5			1.0	0.5	0.25		0.5	NA	6	3.0
WOM					NA	NA	NA	NA	0.25	NA	1	0.25
CTN		NA	NA			NA		NA		NA		
HAW		1.5							0.25	NA	2	1.75
CAL	2.0	0.5			19	NA		NA		NA	3	21.5
GYM						NA		NA		NA		
WHS					NA	NA	NA	NA		NA		
TEX							0.25, 1.5				2	1.75
EGL		1.5				NA	NA	NA		NA	1	1.5
SHIPS (CSQ)					3.0	2.5, 3.0			0.25	NA	4	8.75
TOTAL FAILURES	1	6			4	3	5		4	1	24	
Total Down Time, hours	2.0	12.75			40	6	66.75		1.25	22.5		151.25

* The Down Time is the time from when a function or system was reported "red" until it was reported "green" at a given station. To be conservative, the down times shown are the largest of the down times reported (See refs. 5, 6, 7, 8).

Table V
Gemini Network Station Down Times during GTA-10 Mission
(72.5 hours flight time from Agena launch to Gemini splash)

Station	System	Acq. Aid	C-Band Radars		Timing Standard	Telemetry Down-Link	Command Up-Link	S/C Com. Up-Link Voice	On-Site 1218 Computer	NASCOM TTY	NASCOM HSD	TOTALS	
			Range	Angles								Failures	Down Time (hrs)
MCC-K											NA		
MLA		NA				NA	NA	NA	NA	NA	NA		
CNV											NA		
PAT		NA				NA	NA		NA	NA	NA		
GBI									NA	NA	NA		
GTK									NA		NA		
BDA			0.5	8.0, 0.75								3	9.25
ANT		NA					NA	NA	NA	NA	NA		
CYI											NA		
ASC		NA					NA		NA	NA	NA		
KNO			NA	NA			NA		NA	NA	NA		
PRE		NA				NA	NA	NA	NA	NA	NA		
TAN		0.5	NA	NA			NA		NA		NA	1	0.5
CRO			7.5		4						NA	2	11.5
WOM			0.25		0.75	NA	NA	NA	NA	NA	NA	2	1.0
CTN			NA	NA		1.5, 1.5	NA	1.5, 1.5	NA	NA	NA	4	6.0
HAW							1.0				NA	1	1.0
CAL							NA		NA		NA		
GYM						1.5	NA	8.0			NA	2	9.5
WHS						NA	NA	NA	NA		NA		
TEX													
EGL							NA	NA	NA		NA		
SHIPS											NA		
TOTAL FAILURES		1	3	2	2	3	1	3				15	
Total Down Time, hours		0.5	8.25	8.75	4.75	4.5	1	11					38.75

* The Down Time is the time from when a function or system was reported "red" until it was reported "green" at a given station. To be conservative, the down times shown are the largest of the down times reported (See refs. 5, 6, 7, 8).

Table VI
Gemini Network Station Down Times during GTA-11 Mission
(72 hours flight time from Agena launch to Gemini splash)

System Station		Down Times* in hours for:										TOTALS	
		Acq. Aid	C-Band Radars		Timing Standard	Telemetry Down-Link	Command Up-Link	S/C Com. Up-Link Voice	On-Site 1218 Computer	NASCOM TTY	NASCOM HSD	Failures	Down Time (hrs)
			Range	Angles									
MCC-K	24										NA	1	24
MLA	NA	0.5			NA	NA	NA	NA	NA	NA	NA	1	0.5
CNV									1.0		NA	1	1.0
PAT	NA				NA	NA			NA	NA	NA		
GBI		0.5	0.25			2.75			NA	NA	NA	3	3.5
GTK						1.0			NA		NA	1	1.0
BDA	1.0	2.5, 0.5, 1.0	4.0									5	9.0
ANT	NA		0.5			NA	NA	NA	NA	NA	NA	1	0.5
CYI											NA		
ASC	NA					NA			NA	NA	NA		
KNO		NA	NA			NA			NA		NA		
PRE	NA				NA	NA	NA	NA	NA	NA	NA		
TAN		NA	NA			NA			NA		NA		
CRO		20, 0.5				1.5	2.5	1.5	1.5	NA	NA	5	26
WOM					NA	NA	NA	NA	NA	NA	NA		
CTN		NA	NA			NA			NA		NA		
HAW	5.0									1.75	NA	2	6.75
CAL		0.25				NA			NA		NA	1	0.25
GYM	0.25	0.5, 0.5	0.5			NA	1.5			NA	NA	5	3.25
WHS					NA	NA	NA	NA	NA		NA		
TEX						3.0, 2.0			1.75			3	6.75
EGL						NA	NA	NA	NA		NA		
SHIPS (CSQ)		0.5									NA	1	0.5
TOTAL FAILURES	4	11	4			5	2	3	1			30	
Total Down Time, hours	30.25	27.25	5.25			10.25	4.0	4.25	1.75				83.0

* The Down Time is the time from when a function or system was reported "red" until it was reported "green" at a given station. To be conservative, the down times shown are the largest of the down times reported (See refs. 5, 6, 7, 8).

Table VII
Gemini Network Station Down Times during GTA-12 Mission
(96 hours flight time from Agena launch to Gemini splash)

System Station	Acq. Aid	C-Band Radars		Timing Standard	Telemetry Down-Link	Command Up-Link	S/C Com. Up-Link Voice	On-Site 1218 Computer	NASCOM TTY	NASCOM HSD	TOTALS	
		Range	Angles								Failures	Down Time (hrs)
MCC-K				3	5					NA	2	8
MLA	NA				NA	NA	NA	NA	NA	NA		
CNV										NA		
PAT	NA				NA	NA		NA	NA	NA		
GBI								NA		NA		
GTK								NA		NA		
BDA	2.5, 2.5	3, 4			2		3				6	17
ANT	NA	8				NA	NA	NA	NA	NA	1	8
CYI										NA		
ASC	NA				90	NA	8	NA	NA	NA	2	98
KNO		NA	NA		12	NA	3	NA	NA	NA	2	15
PRE	NA				NA	NA	NA	NA	NA	NA		
TAN		NA	NA			NA		NA		NA		
CRO		96		2.5	3	2, 4, 3, 3, 4				NA	8	117.5
WOM					NA	NA	NA	NA		NA		
CTN		NA	NA			NA	8	NA		NA	1	8
HAW					3	2, 3		3		NA	4	11
CAL	10	3, 12, 4, 3, 4, 2				NA	4	NA		NA	8	42
GYM		6		2, 2		NA	20			NA	4	30
WHS					NA	NA	NA	NA		NA		
TEX						6	3				2	9
EGL	96	96				NA	NA	NA		NA	2	192
CSQ				2.5			4, 2			NA	3	8.5
SHIPS WHE		5								NA	1	5
RKV	96									NA	1	96
TOTAL FAILURES	5	13		5	6	8	9	1			47	
Total Down Time, hours	207	246		12	115	27	55	3				665

* The Down Time is the time from when a function or system was reported "red" until it was reported "green" at a given station. To be conservative, the down times shown are the largest of the down times reported (See refs. 5, 6, 7, 8).

Table VIII

Summary of Gemini Ground Systems Down Times
in Percent of Mission Support Time*
for GTA-9, 10, 11, and 12
(Total Flight Time = 361 hours)

System or Function	% of Time Down During Manned Space Flight
Acquisition	3.7
C-Band Radar:	
Range	4.8
Angles	0.23
Timing Standard	0.21
Telemetry (Down-Link)	2.5
Command (Up-Link)	0.65
Voice (Up-Link)	2.4
On-Site Computer (1218)	0.20
NASCOM	
TTY	0.041
HSD	3.1

*The Down Time is the time from when a function or system was reported "red" until it was reported "green" at a given station. To be conservative, the down times shown are the largest of the down times reported (See refs. 5, 6, 7, 8). The mission support time is the product of the total flight time from Agena launch to Gemini splash and the number of ground systems.

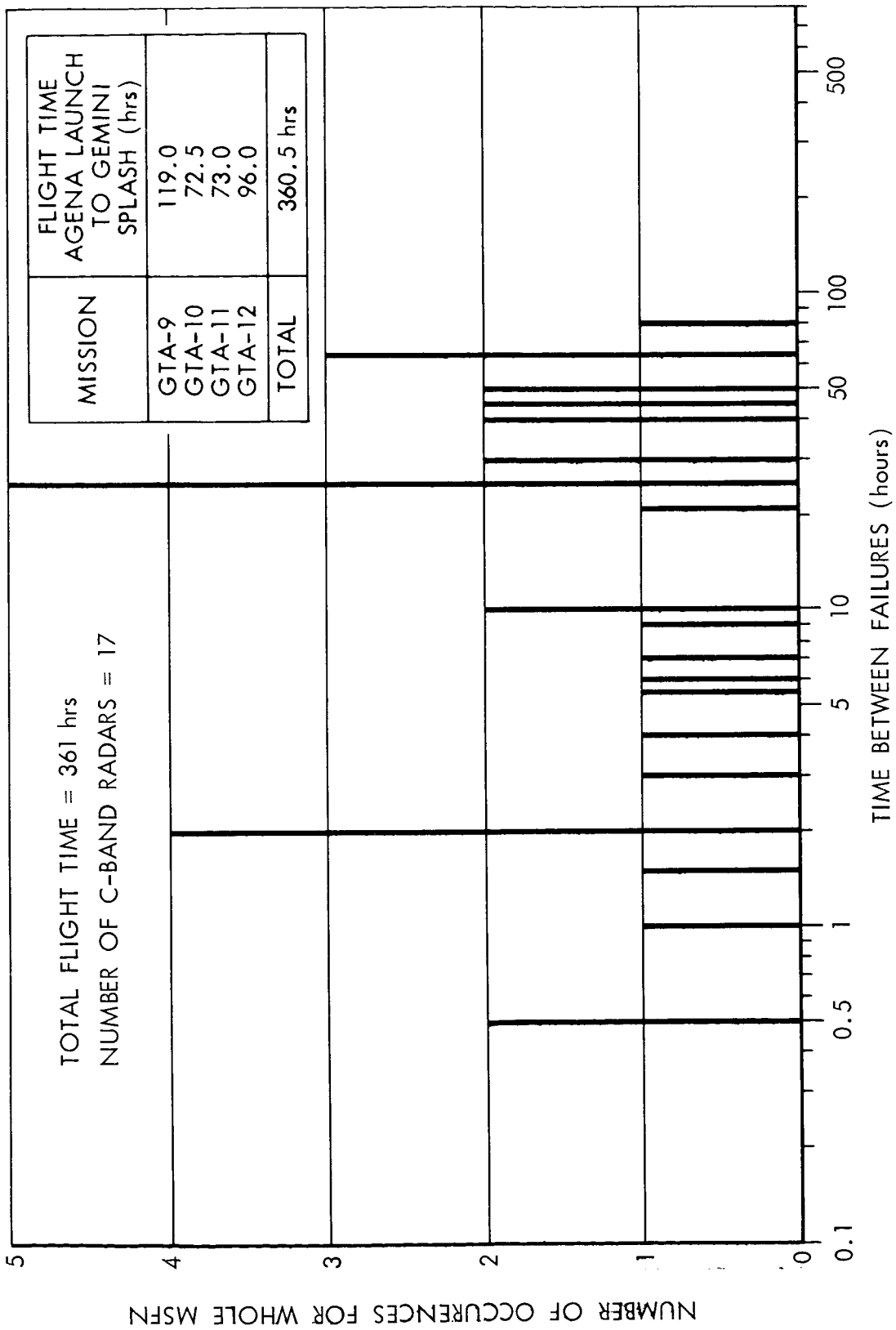


Figure 1a. Unnormalized Time Between Failures Histogram for C-Band Radar Range Measurements During GTA-9, 10, 11, and 12 Flights

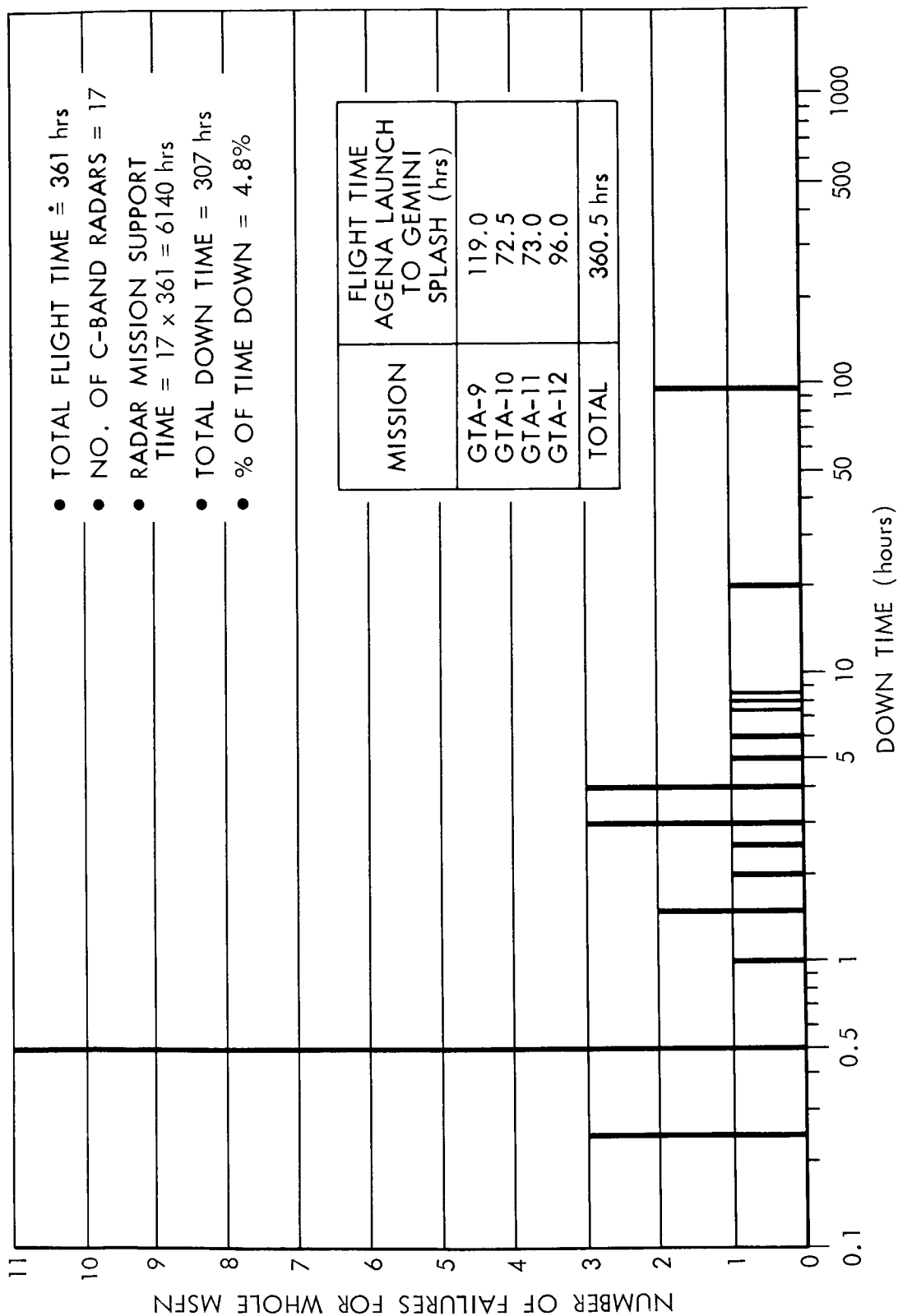


Figure 1b. Unnormalized Down Time Histogram for C-Band Radar Range Measurements During GTA-9, 10, 11, and 12 Flights

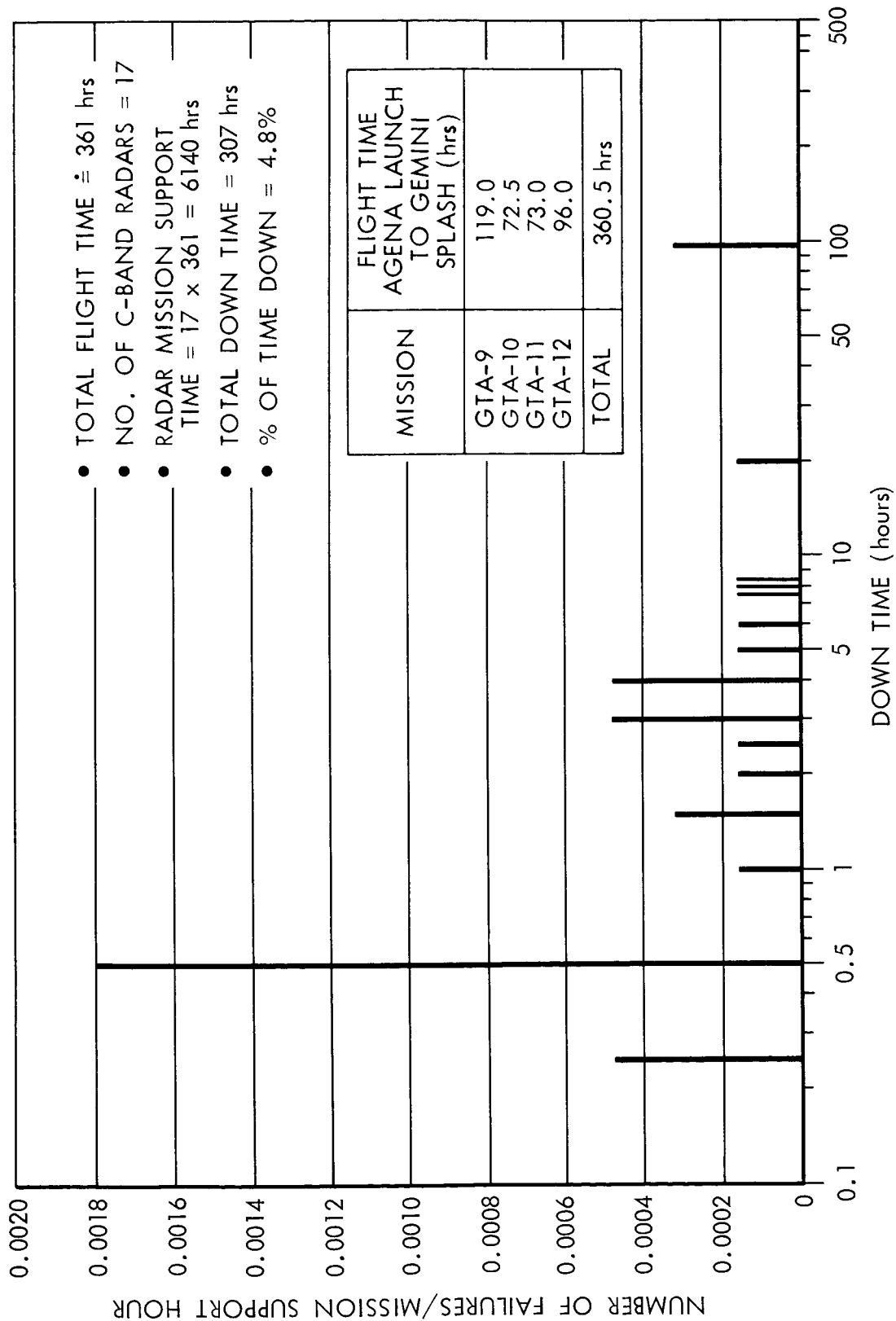


Figure 2. Normalized Down Time Histogram for C-Band Radar Range Measurements During GTA-9, 10, 11, and 12 Flights

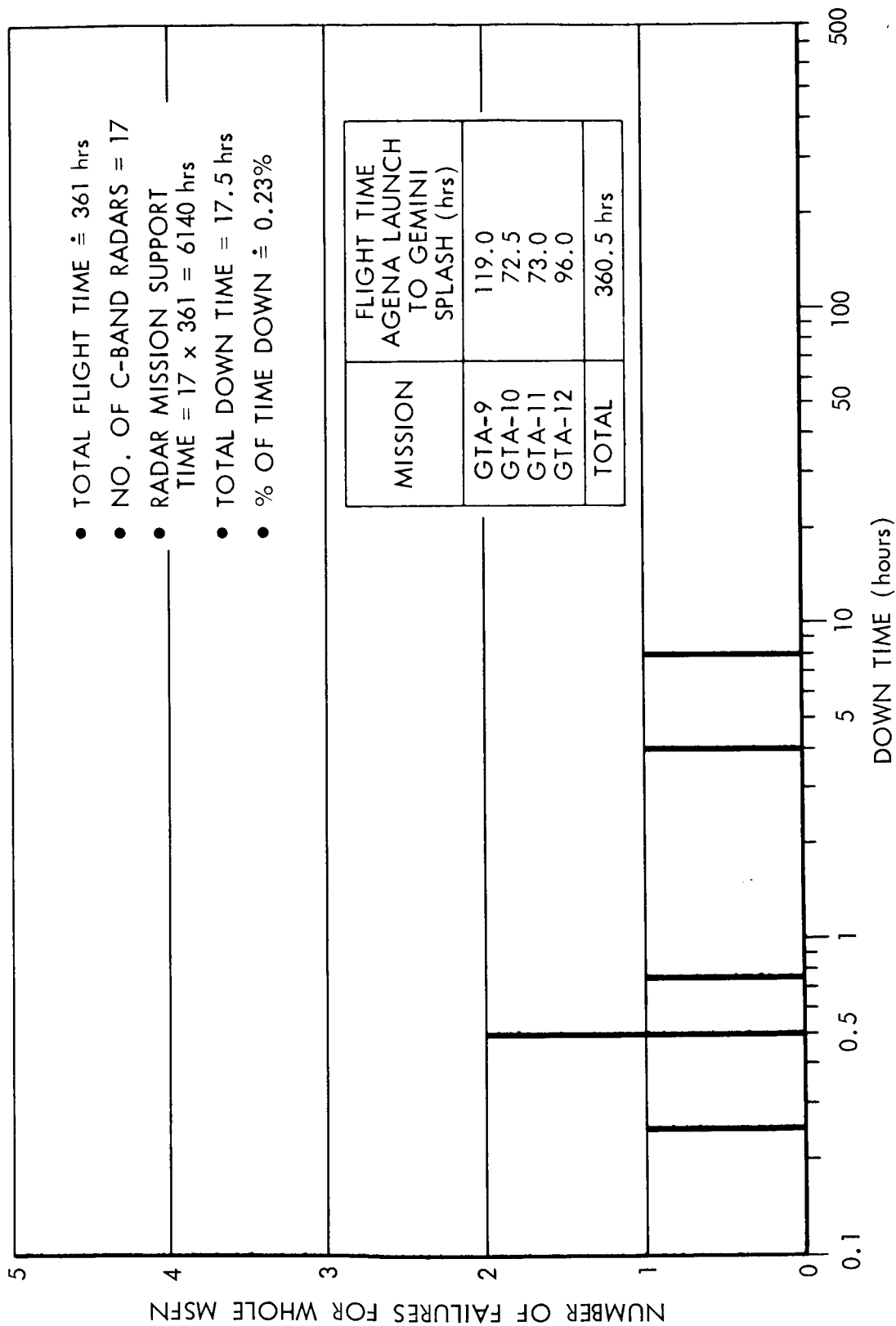


Figure 3. Unnormalized Down Time Histogram for C-Band Radar Angle Measurements During GTA-9, 10, 11, and 12 Flights

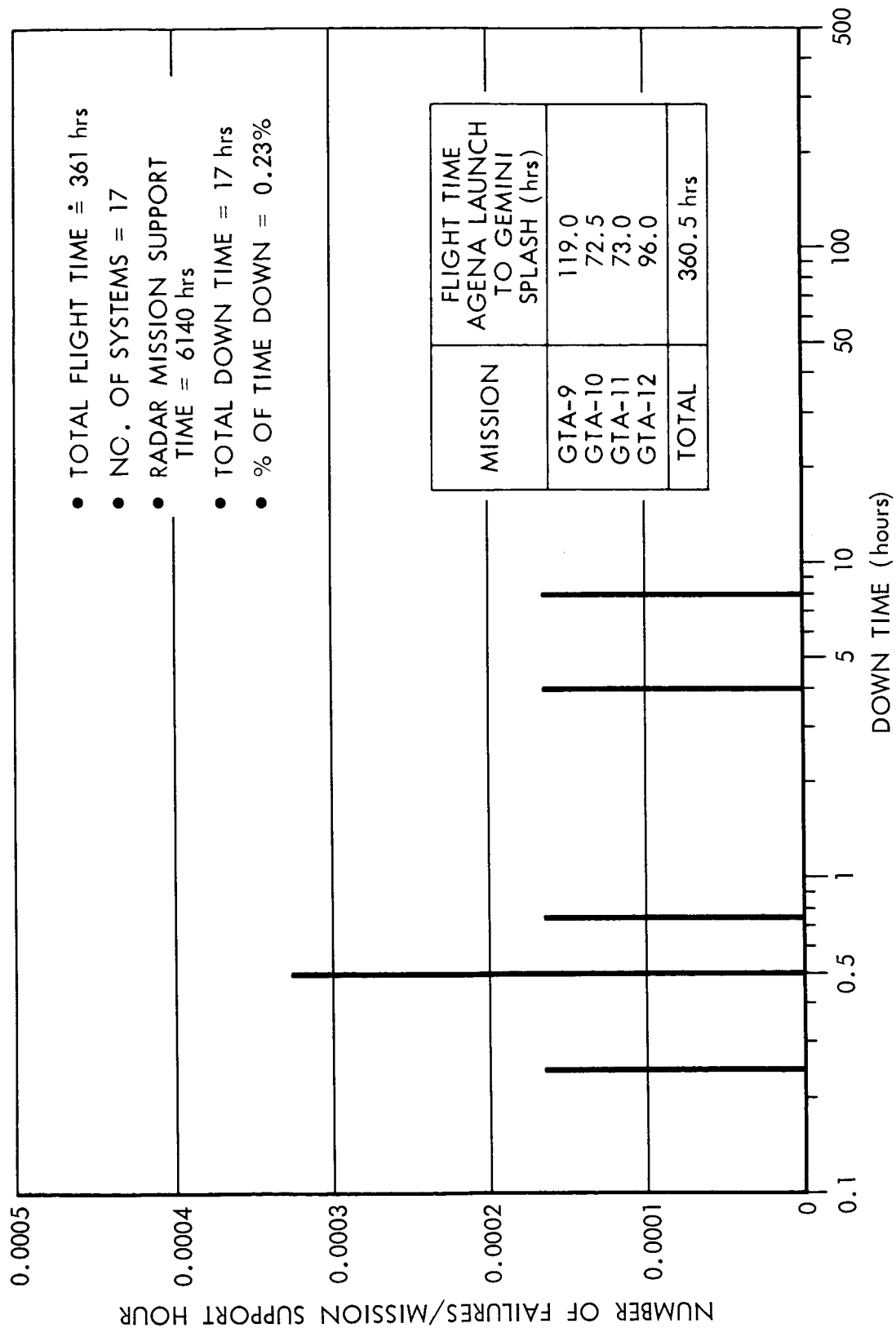


Figure 4. Normalized Down Time Histogram for C-Band Radar Angle Measurements During GTA-9, 10, 11, and 12 Flights

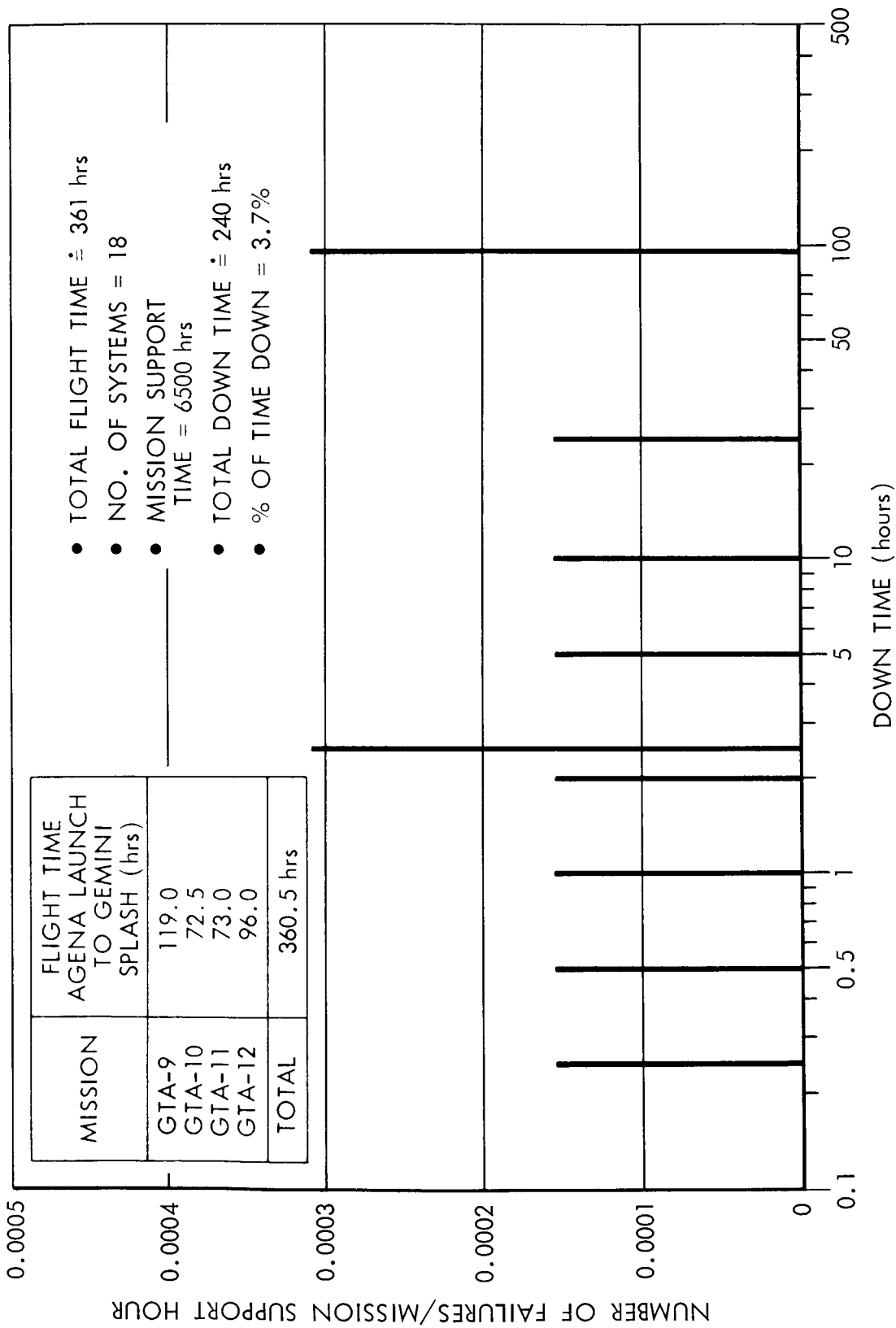


Figure 5. Normalized Down Time Histogram for Acquisition Aids During GTA-9, 10, 11, and 12 Flights

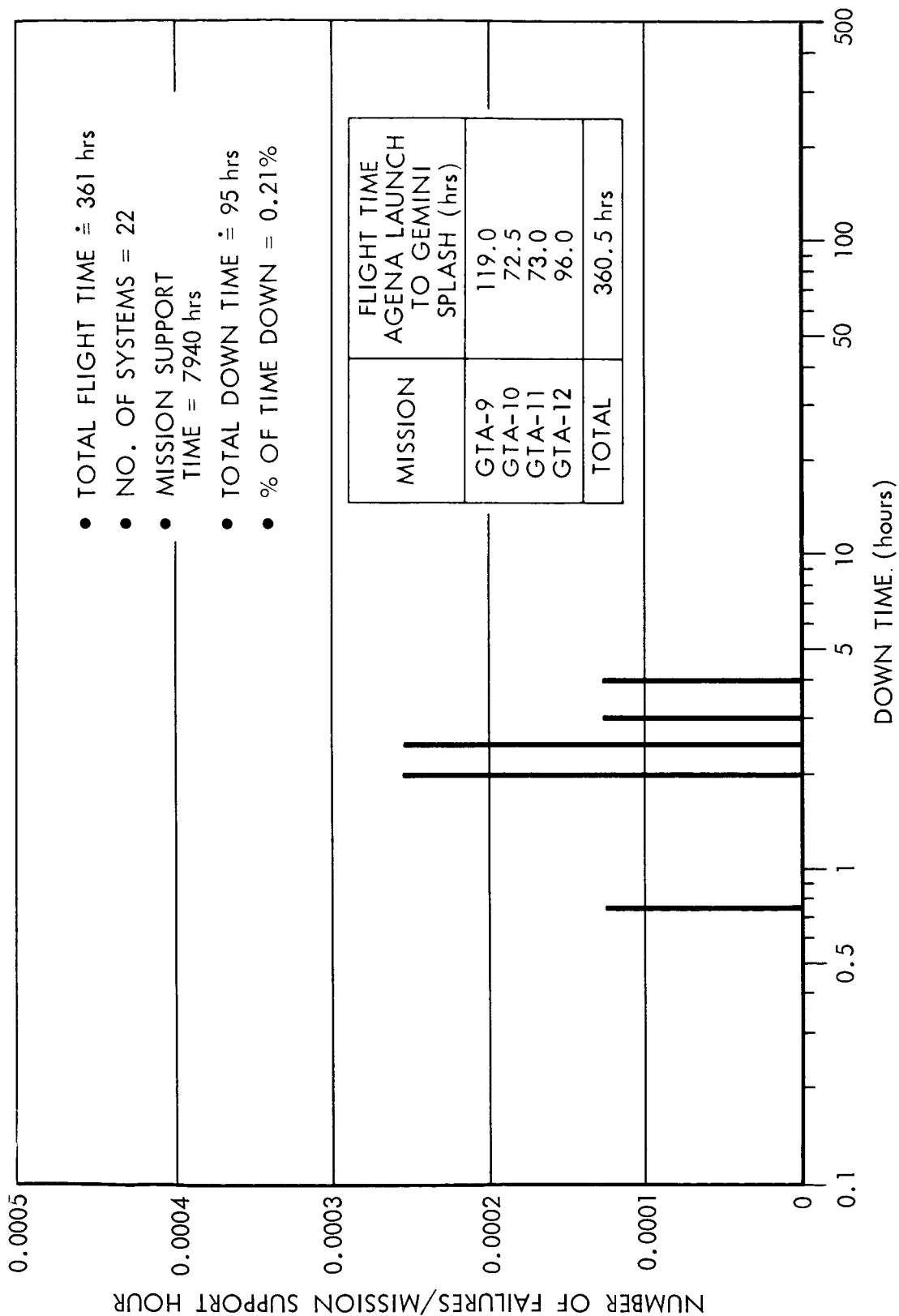


Figure 6. Normalized Down Time Histogram for Station Timing Standard During GTA-9, 10, 11, and 12 Flights

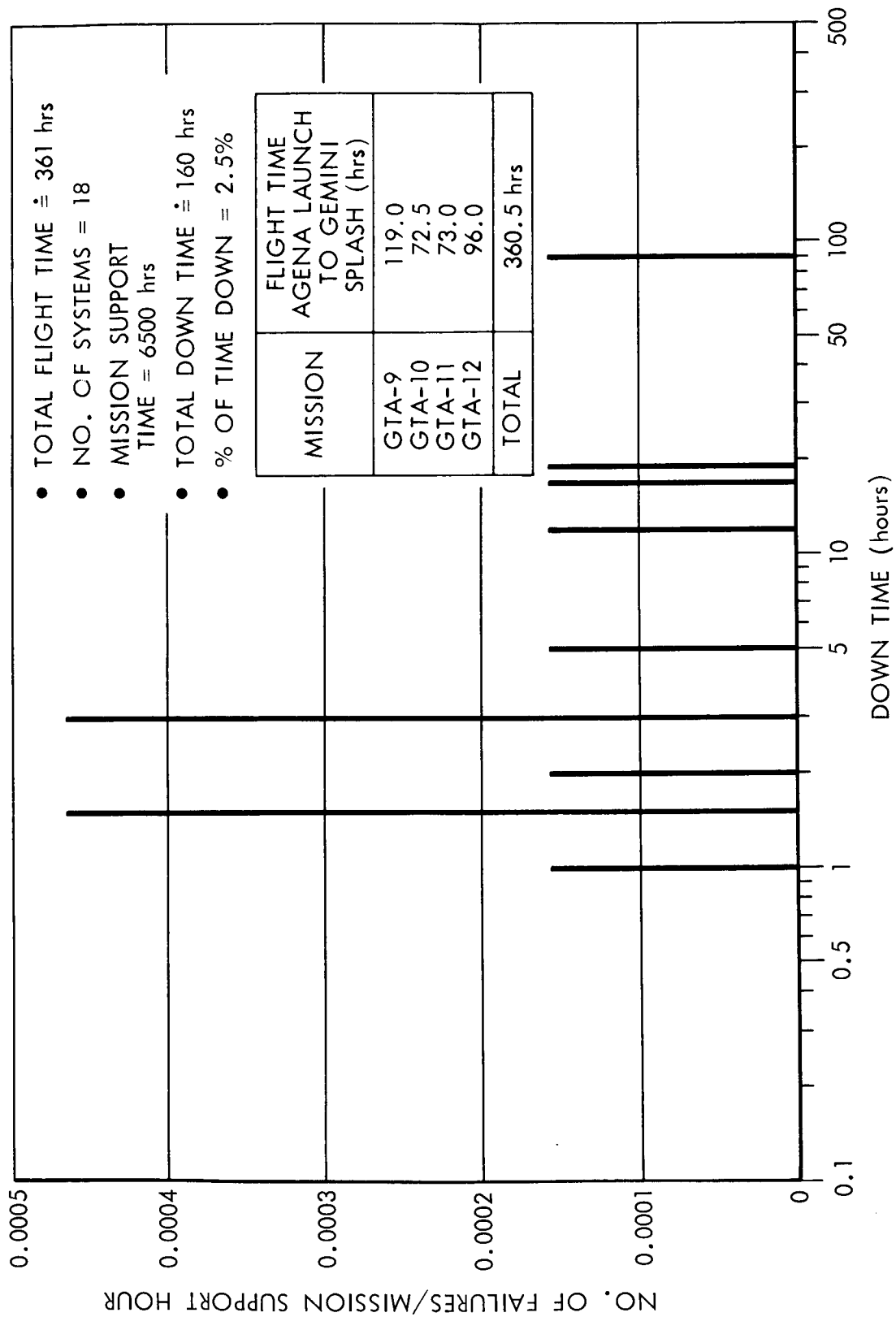


Figure 7. Normalized Down Time Histogram for Down Link Telemetry Ground Systems During GTA-9, 10, 11, and 12 Flights

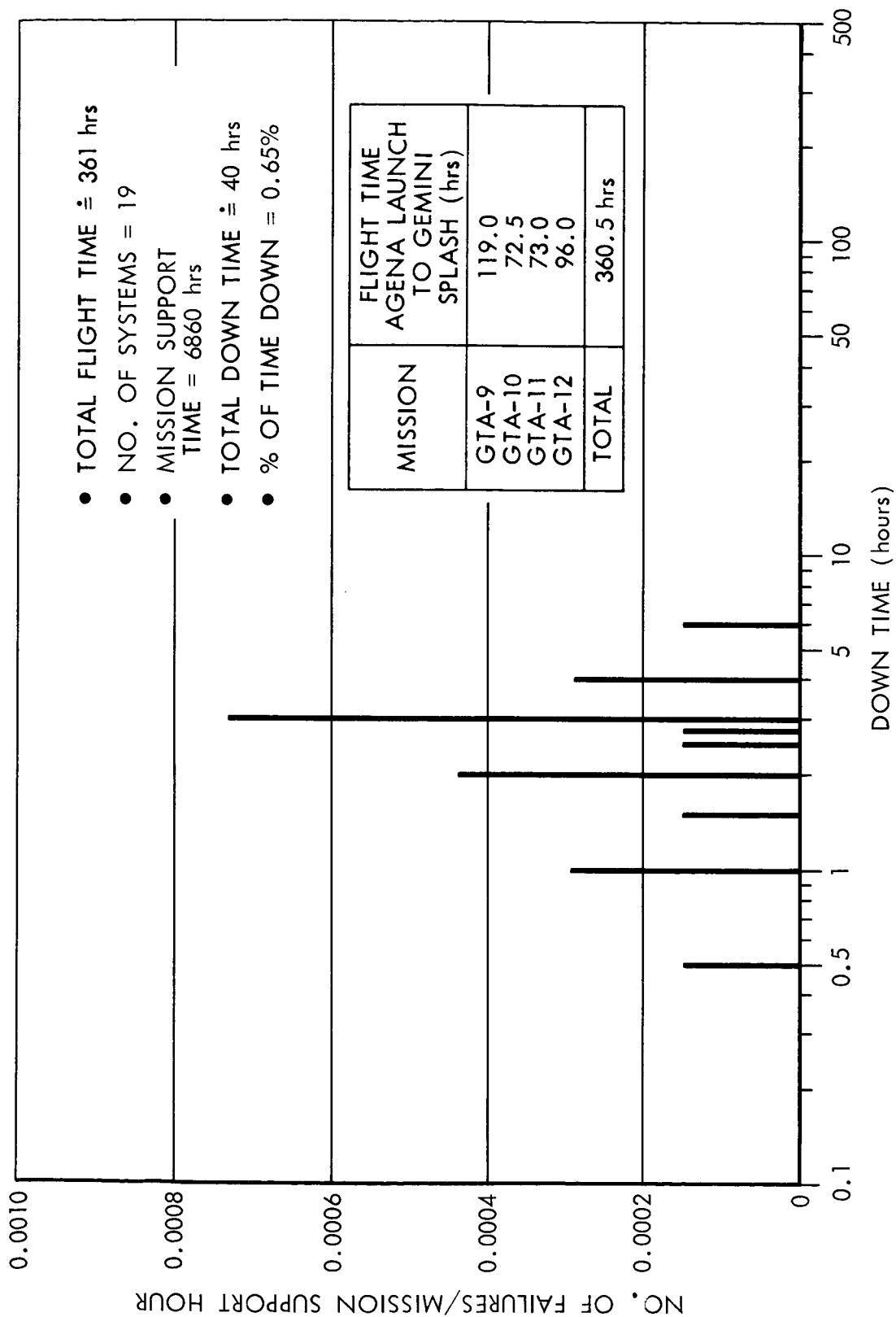


Figure 8. Normalized Down Time Histogram for Ground Up-Link Command Systems During GTA-9, 10, 11, and 12 Flights

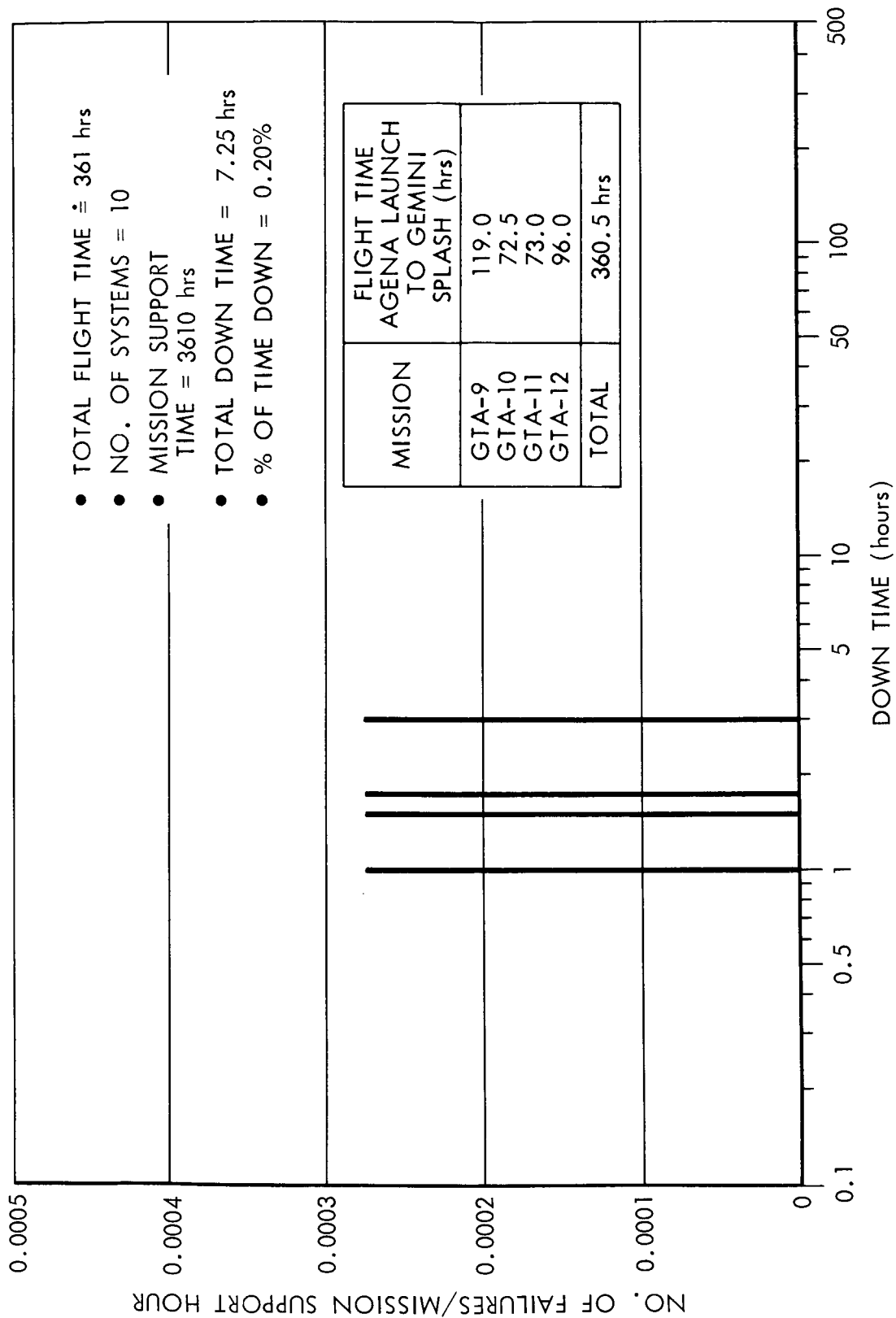


Figure 9. Normalized Down Time Histogram for On-Site 1218 Computer During GTA-9, 10, 11, and 12 Flights

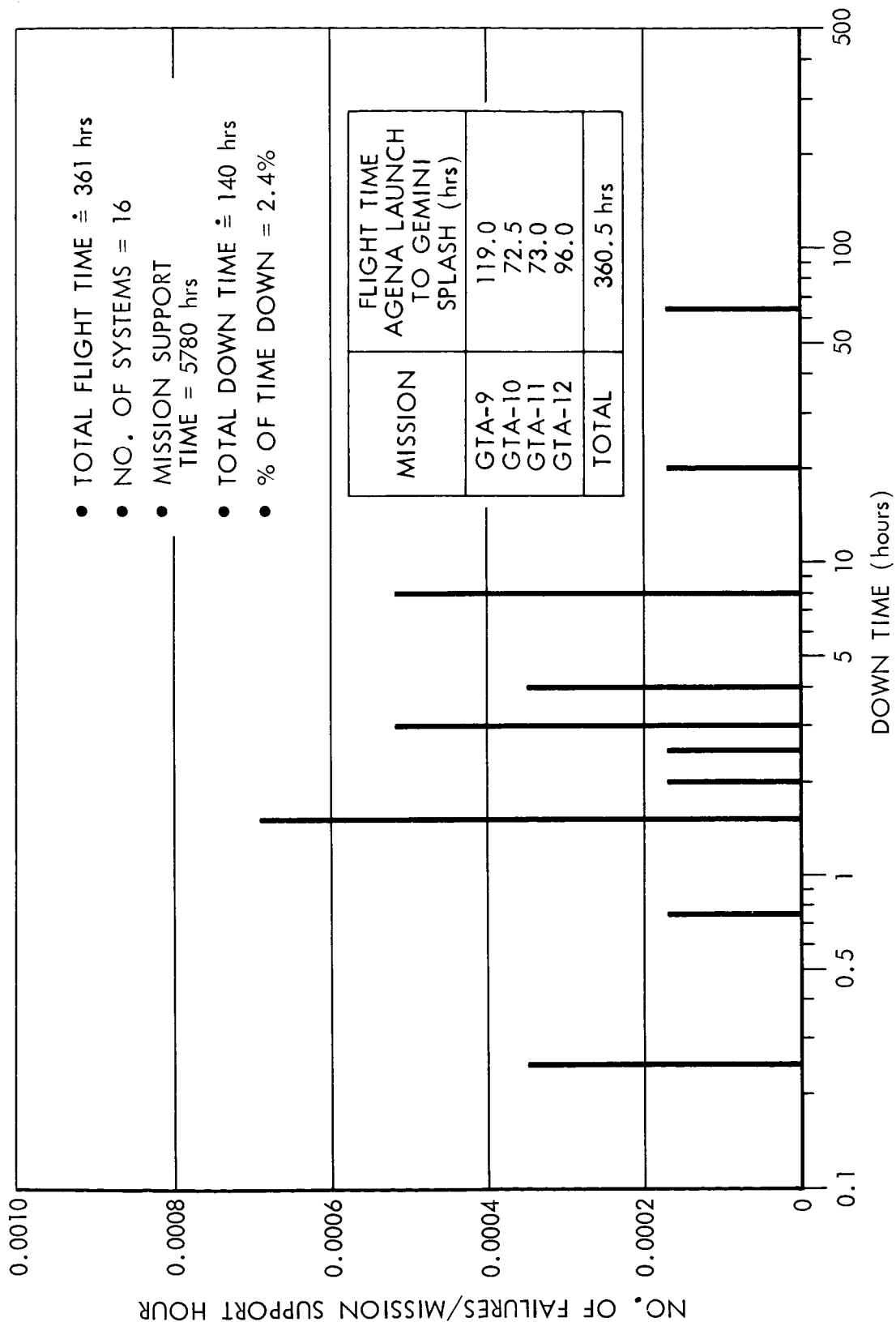


Figure 10. Normalized Down Time Histogram for Ground Spacecraft Communications Systems (Ground Up-Link Voice), During GTA-9, 10, 11, and 12 Flights

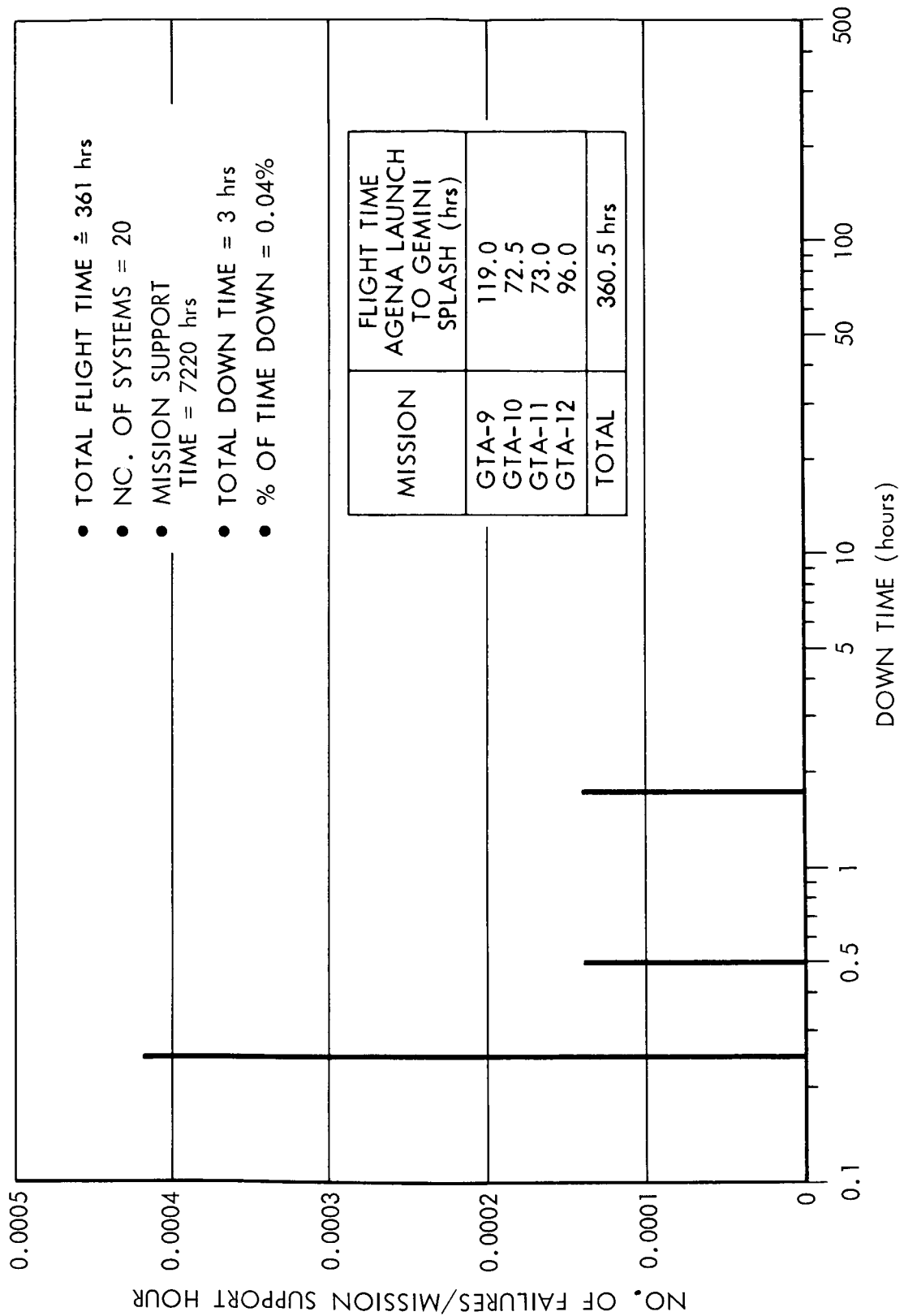


Figure 11. Normalized Down Time Histogram for NASCOM Teletype Systems During GTA-9, 10, 11, and 12 Flights

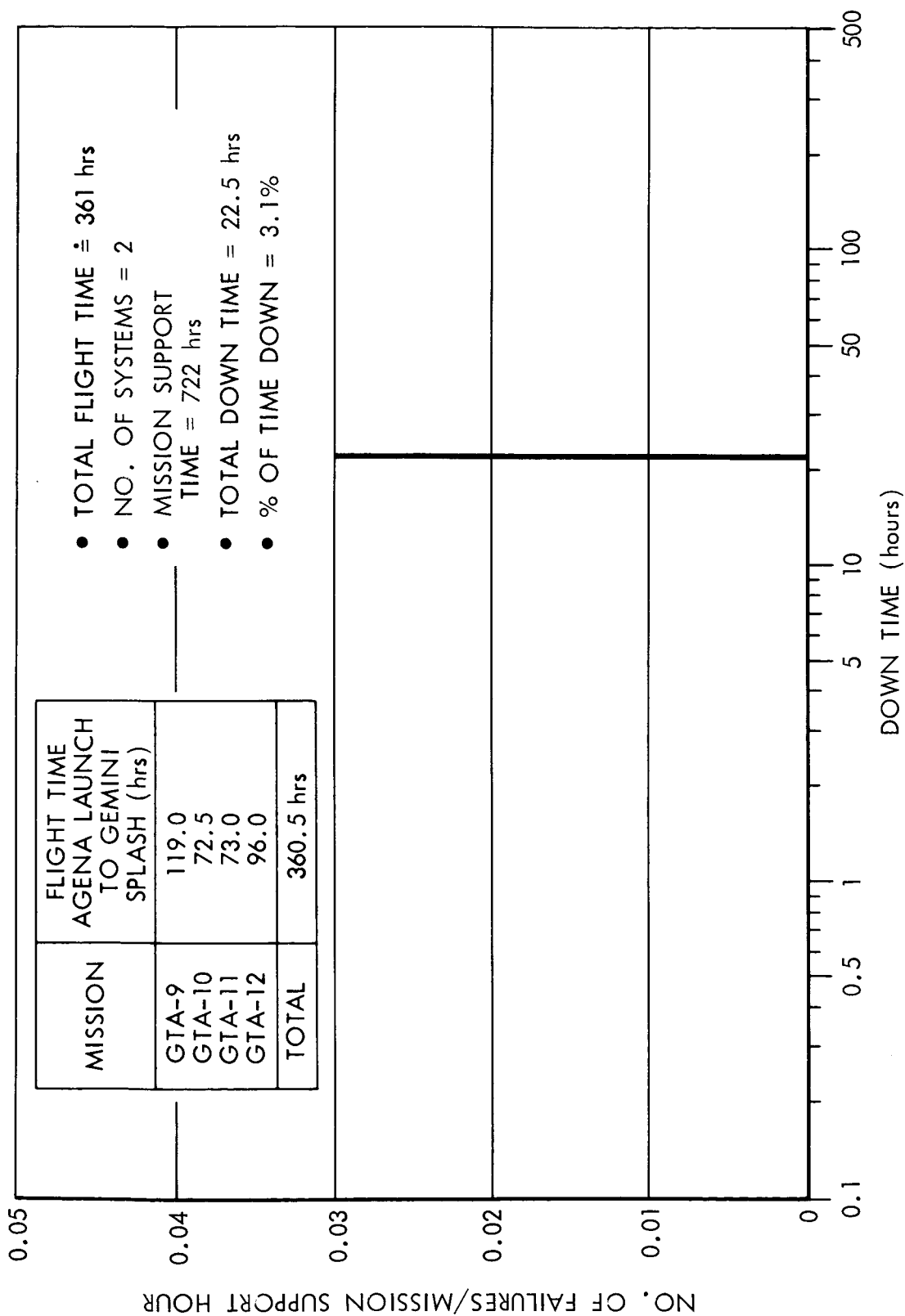


Figure 12. Normalized Down Time Histogram for NASCOM High Speed Data Systems During GTA-9, 10, 11, and 12 Flights